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THE EFFECTIVENESS OF FADING IN PROGRAMMING A SIMULTANEOUS FORM DISCRIMINATION FOR RETARDED CHILDREN[1]

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A non-verbal teaching program, combined with reinforcement and extinction (Program Group), was compared with reinforcement and extinction alone (Test Group) in teaching retarded children to discriminate circles from ellipses. In the Program Group, fading techniques were used to transfer stimulus control from "bright *vs.* dark" to "form *vs.* no-form" and then to "circle *vs.* ellipse". The Test Group had the task of learning the circle-ellipse discrimination with no prior teaching program. With the program, seven of 10 children learned the circle-ellipse discrimination. Without the program, one of nine learned. The eight Test-Group children who failed to learn circle *vs.* ellipse were then given the opportunity to learn the form no-form discrimination by reinforcement and extinction alone, without fading. Six of the eight learned, but only three of these six then learned circle *vs.* ellipse on a second test. All seven Program-Group children who had learned form *vs.* no-form also learned the circle-ellipse discrimination by means of fading; each of the seven made fewer errors than any of the three who succeeded on the second test. Children who failed to learn circle *vs.* ellipse adopted response patterns incompatible with the development of appropriate stimulus control.

In applying "shaping" techniques to facilitate the learning of new responses, the teacher starts by reinforcing behavior that the learner already has or can acquire easily. He then gradually restricts the application of reinforcement to behavior that more closely resembles the performance he wants to teach. In discrimination learning, the analogue of response shaping is stimulus shaping. The teacher starts by reinforcing a stimulus-response relation that the learner already has or can acquire easily, and gradually changes the stimuli until he arrives at the restricted stimulus-response relation he wants to teach.

Terrace, building on earlier experiments by Schlosberg and Solomon (1943), Lawrence (1952), and Baker and Osgood (1954), used several methods of stimulus shaping, or "fading", to teach stimulus-response relations to pigeons. He began with birds that pecked an illuminated key and refrained from pecking the key when it was dark. He shaped the stimuli along a temporal dimension, gradually increasing the length of time the key was dark on each trial. Terrace then transferred the basis for the discrimination by gradually fading colors onto the key, so that the pigeons continued to peck the key when it was red, but did not peck when it was green (Terrace, 1963*a*). Additional stimulus shaping was accomplished by superimposing lines on the colored key and then gradually fading out the colors, thereby teaching the birds to peck the key when it had a vertical line on it and not to peck when the line was horizontal (Terrace, 1963*b*).

When Terrace used temporal shaping, birds were able to learn the original brightness discrimination without ever pecking the dark key. Similarly, the pigeons transferred to the red-green discrimination and then to the horizontal-vertical discrimination without ever pecking the negative stimulus, *i.e.*, without making a single error.

Errorless discrimination learning challenges the prevalent view that stimulus-response learning can be described as a process of error elimination. If a subject can learn without

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making errors, it is reasonable to infer that errors are secondary phenomena, products of teaching methodology rather than of the learning process itself (Skinner, 1961).

A second inference, if justified, could lead to far-reaching practical consequences. If errors can be eliminated from the learning process, perhaps the teaching methods that accomplish this will make learning easier for those who ordinarily have difficulty. As Holland (1965) has pointed out, the elimination of errors is a valid objective only if it is accompanied by the establishment of behavior that is prerequisite if the learner is to overcome his difficulties. If this requirement is met, it is a tautology to say that the elimination of errors may make learning easier, but the necessity of this relation seems not to be generally appreciated among teachers and learning theorists. Currently, there is much discussion of the value and even the necessity of errors in the process of learning (see Holland, 1965, for a recent review).

The present experiment attempted to check these inferences using retarded children as subjects. A teaching program based on stimulus shaping, or fading, along with reinforcement, was compared to the same reinforcement techniques without stimulus shaping. The objective of both sets of procedures was to help the children to learn to distinguish circles from ellipses.

METHOD

Subjects

Nineteen retarded boys, their chronological ages ranging from 9-9 (nine years and nine months) to 14-4, and all institutionalized for periods ranging from three years and eight months to 13 years, served. The six most advanced children could understand simple instructions, and three of them could use poorly articulated speech to make their simplest needs known. Most of the children rarely, if ever, spoke, and gave little indication that they understood spoken language. The boys all lived in the same building. All the children in the building were given relative rankings for their potential levels of development as judged

Table 1

Characteristics of the Children

Relative Ranking	*Most Recent I.Q. or S.Q.*[1]	*Age*	*Institutionalized Since Age*	*Most Recent Clinical Impressions*
	Program Group			
1.5[2]	32	12–4	1–1	Posticteric encephalopathy, with athetoid posturing, and myoclonic jerking.
3	30	13–6	4–2	Familial microcephaly; cleft palate, partially repaired.
6	30	12–1	4–1	Familial microcephaly; spastic diplegia.
8	27	14–3	4–11	Mild spastic diplegia.
9	34	9–9	9 days	Mongolism.
11	28	10–5	1–2	Mongolism.
14	27	14–2	1–2	Mongolism.
17	23	13–11	1–1	Mongolism.
18	18	12–0	5–6	Spastic diplegia with athetoid posturing.
19	31	10–1	6–5	Microcephaly; question of mosaic mongolism.
	Test Group			
1.5[2]	38	11–0	3–5	Moderate mental retardation.
4	35	13–10	4–7	Moderate mental retardation.
5	34	14–1	6–0	Mongolism; congenital heart disease.
7	35	13–5	1–4	Mongolism.
10	28	13–11	3–0	Spastic diplegia, perhaps secondary to neonatal sepsis and anoxia.
12	38	11–5	7–6	Mongolism.
13	18	11–11	1–3	Mongolism.
15	39	14–4	5–2	Mongolism.
16	35	12–0	2–8	Right porencephalic cyst; hydrocephalus.

[1]I.Q. was obtained by means of the 1916 Binet-Simon Test; S.Q., by the Vineland Social Maturity Scale.

[2]These two children tied for the highest rank.

by 13 staff members who had worked closely with them in both daily care and training for periods ranging from six months to 15 years. A Test Group and a Program Group were closely equated on the basis of their rankings. Table 1, which lists the children of the two groups according to their relative ranks, also presents standardized test data and other information obtained from the institutional records. The two groups were closely matched with respect to rankings, test scores, and chronological ages.

Apparatus

The children were transported by automobile from their institution to the hospital laboratory. They were allowed to play for a while, in order to adapt them to the laboratory situation, before being taken into the experimental chamber. This was a room about 5 ft square, with sound-resistant walls and door. The door was not locked, and the child could leave the room and terminate the experiment at any time. One child in the Test Group did so. The subject sat on a chair of adjustable height, facing a square matrix of nine keys. Figure 1 shows the nine-key matrix, with the outer keys illuminated and the center key dark. Beside the key matrix were plastic trays into which automatic devices delivered candies (M&M's) as reinforcers. Just below the keys was a shelf on which the child could place his candies. A set of chimes was located high on the wall above the child's chair.

Each of the nine individual keys on the matrix was a translucent plastic (Polacoat) 2 by 2-in. square. A Leitz automatic slide projector, located on the other side of the wall from the child, projected stimuli on the keys from the rear. When the stimuli were displayed, the child's task was to press one of the keys. A small microswitch behind each key signaled the child's choice to the automatic control and recording apparatus. Photocells beside the keys (on the other side of the wall and not visible to the child) decoded the key that was correct on any given trial. All the stimuli to be presented on a given trial, along with the pattern of illumination of photocells, were photographed on 35 mm color film and mounted in slides. A shutter on the projector kept transient light from the photocells while slides were changing. Shutters were also mounted behind the keys so that stimuli could be made to appear and disappear rapidly. The motor-driven shutters, the slide projector, photocells, rewarding devices, and recording equipment were controlled automatically by solid-state electronic components. Hively (1962, 1964) and Holland (1961) have described a similar apparatus.

Recordings were provided by two instruments. One was an Esterline-Angus operations recorder, which gave a trial-by-trial temporal record of the correct key and all keys the child pressed. The other was a Gerbrands cumulative recorder, modified by coupling the pen via a chain and pulley to the rear of the projector's slide tray. When the slide tray advanced to project successive slides, it pulled the pen up the paper, and when the slide tray reversed (see Procedure, below), the pen retreated. This recording method provided a continuous temporal picture of the child's progress through a given series of slides (Holland, personal communication, 1962).

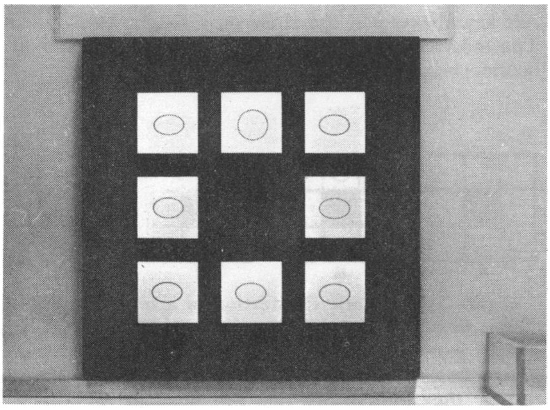

Fig. 1. The key matrix.

Procedures, All Subjects

The child was seated before the key matrix with the chair adjusted to bring his eyes to the level of the center key. Magazine training was accomplished with one or two candy deliveries. The experimenter then pressed a button that presented the first stimulus array on the keys and sat down behind the child. The child was told to "press the key" or "push the button". Most of the children did not understand these simple instructions, but they were given to each one. The experimenter said nothing more and ignored all attempts of the child to interact with him.

Whenever the child pressed a correct key, the shutters closed, blanking out the stimuli. When he released the key, ending the trial, the chimes sounded, the reward dispenser operated, and the projector presented the next slide. Some children ate their candies immediately, and others saved them in a paper cup. A 1.5-sec delay separated the end of one trial and the beginning of the next. The position of the correct key always changed from trial to trial.

A correction procedure was used; when the child pressed a wrong key, the stimuli remained until he corrected his error. A trial always ended with a correct choice. If the child pressed two or more keys simultaneously, it counted as an error, even if one was the correct key.

A "backup" procedure was also used (Holland, 1961). If the child made one or more errors on a given trial, his final correct response on that trial caused the slide tray to reverse, thus exposing the preceding array of stimuli again. The slide tray advanced only if the child's first choice on a given trial was correct. In the Program Group, this backup procedure ensured that the child returned to an easier step in the program after an error. In the Test Group, the backup procedure was included as a control. The backup procedure was not used if the child made an error on the first slide of a series, since this would have disengaged the slide tray from the projector. Therefore, the child always advanced from slide 1 to slide 2, even if he had made an error on slide 1.

Each child continued on a given procedure until he completed the series of slides or met the error criterion, the criterion for failure to learn, which was at least one error on five consecutive presentations of the same slide. Because of the backup procedure, a child could not meet the error criterion in less than nine trials. The array of nine keys automatically provided a relatively stringent criterion for learning. Random selection by the child would yield a correct first response on only one of nine trials; two consecutive correct choices would occur only once in 81 trials; *etc.*

Stimuli were presented only on the eight outside keys of the matrix; the center key was always dark, and was never a correct choice. For both groups, and in all series of slides, the correct choice was always the key on which a circle was projected.

Procedures, Program Group

The program for teaching the circle-ellipse discrimination had two stages, background fading (slides 1 to 7) and ellipse fading (slides 8 to 17). The development of this program has been described elsewhere (Sidman and Stoddard, in press).

I. Background fading. Figure 2 is a schematic illustration of a few steps in the background-fading series. Slide 1 presented the child with a circle on one bright key, and eight dark keys; he had only to make a brightness discrimination at this point. The incorrect keys became brighter from slide to slide until, on slide 7, all keys were equally bright but only the correct key had a form (circle) on it. This series of slides was designed to transfer discriminative control from "bright key *vs.* dark keys" to "key with a form *vs.* keys with no form".

II. Ellipse fading. On slide 8, an ellipse appeared faintly on each incorrect key; with successive slides, the ellipses became more distinct. By slide 17, the ellipses and circle were equally distinct. This series of slides was designed to transfer discriminative control from "form *vs.* no form" to "circle *vs.* ellipse", the criterion discrimination. Figure 3 is a schematic illustration of a few steps in the ellipse-fading series.

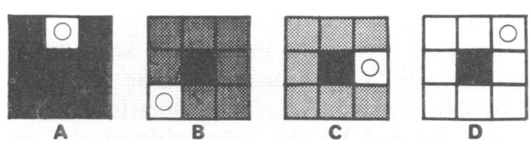

Fig. 2. Schematic illustration of a few steps in the background-fading portion of the program. The correct key always had the circle on a bright background. The incorrect keys were dark at first (A) and gradually became brighter (B, C, D).

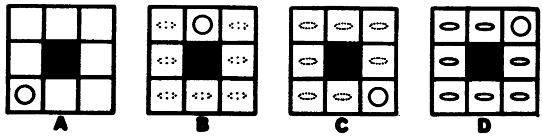

Figure 3. Schematic illustration of a few steps in the ellipse-fading portion of the program. The ellipses appeared gradually (B, C, D), on the bright backgrounds of the incorrect keys. (The ellipses were not actually dotted; they were drawn that way here for convenience in reproduction.)

Procedures, Test Group

Children of the Test Group were first exposed to a series of slides which required them to distinguish circles and ellipses without any fading program. Those who failed to complete the criterion test series were then exposed to earlier criterion or teaching portions of the program to determine which levels were necessary to teach them the circle-ellipse discrimination.

I. "Circle vs. ellipse" test. The children were first exposed to 10 slides (the same number and the same sequence of correct keys as ellipse fading) that required the final criterion performance (Fig. 3D)—circle *vs.* ellipse—with no prior teaching program.

II. "Form vs. no-form" test. Children who failed to learn the circle-ellipse discrimination in the first test series were exposed to seven slides (the same number and the same sequence of correct keys as background fading) requiring the form *vs.* no-form discrimination (Fig. 2D), with no prior teaching program. Those who learned this discrimination were then given the circle-ellipse test a second time.

III. Ellipse fading. Children who failed to learn the circle-ellipse discrimination after passing the "form *vs.* no-form" test were given the ellipse-fading slides (Fig. 3).

IV. Background fading. Children who failed to learn the form *vs.* no-form discrimination by means of the test were given the background-fading slides (Fig. 2), and if they then learned the form no-form discrimination, they were given the ellipse-fading slides (Fig. 3).

RESULTS

Table 2 shows the number of errors each child made on all the indicated series of slides, and designates whether or not the child mastered each series. The children are identified by their rankings, corresponding to the first column of Table 1.

Total program vs. first circle-ellipse test. Seven of the 10 children who were given the background- and ellipse-fading slides succeeded in learning the circle-ellipse discrimination (Line C of Table 2). Of nine children in the Test Group, only Child 4 learned the circle-ellipse discrimination by means of the

Table 2

Learners (+), Non-learners (−), and Errors in Each Successive Procedure

Consecutive Procedures	Program Group Subjects 1.5	3	6	8	9	11	14	17	18	19
A. Background Fading	+ 0	+ 2	+ 22	+ 0	+ 0	+ 1	− 122	− 261	+ 10	− 234
B. Ellipse Fading	+ 1	+ 1	+ 3	+ 2	+ 13	+ 1			+ 13	
C. Combined Total	+ 1	+ 3	+ 25	+ 2	+ 13	+ 2	− 122	− 261	+ 23	− 234

Consecutive Procedures	Test Group Subjects 1.5	4	5	7	10	12	13	15	16
D. First Circle-Ellipse Test	− 47	+ 18	− 45	− 67	− 156	− 39	− 113	− 124	− 183
E. Form No-Form Test	+ 8		+ 0	+ 4	− 34	+ 4	+ 47	+ 13	− 48
F. Second Circle-Ellipse Test	− 23		+ 58	+ 35		+ 35	− 126	− 72	
G. Ellipse Fading	− 13						− 32	+ 43	
H. Background Fading					− 28				+ 6
I. Ellipse Fading									− 34
J. Combined Total	− 91	+ 18	+ 103	+ 106	− 218	+ 78	− 318	+ 252	− 271

reinforcement and extinction procedures employed in the first circle-ellipse test (Line D of Table 2).

None learned the discrimination without errors, but Subject 4, the only one of the Test Group to learn the discrimination at this point, made more errors (18) than five of the seven learners in the Program Group.

Ellipse fading vs. first circle-ellipse test. Line C of Table 2 combines the children's errors on the background-fading and ellipse-fading portions of the program. Line B shows their performance on the ellipse-fading series only (Children 14, 17, and 19 did not progress as far as ellipse fading). All seven children of the Program Group who had first learned the form no-form discrimination went on to learn the circle-ellipse discrimination via ellipse fading; all made fewer errors than the one child in the Test Group who learned the discrimination (Line D).

Ellipse fading vs. circle-ellipse test after children learned the form no-form discrimination. The eight children of the Test Group who had failed to learn the circle-ellipse discrimination on the first test were then given the "form no-form" test in order to determine: (a) whether they would learn the form no-form discrimination without the help of background fading; and (b) if they succeeded in learning the form no-form discrimination, would this be sufficient to help them through a second exposure to the circle-ellipse test?

Six of the eight children learned the form no-form discrimination via the test (Line E of Table 2), a favorable comparison with the seven of 10 children who learned it with the aid of background fading (Line A). There is only a slight trend toward fewer errors by the children who succeeded in the background-fading series. The children of both groups, therefore, appear little different after learning the form no-form discrimination.

The six children of the Test Group who had learned the form no-form discrimination were then given the circle-ellipse test a second time. Line F of Table 2 summarizes their performance. Only three (5, 7, and 12) of the six succeeded in mastering the circle-ellipse discrimination; all seven children who went through the ellipse-fading series after mastering form *vs.* no-form were successful (Line B). Each of the three children in the Test Group made more errors in learning the circle-ellipse discrimination than any of the seven children who learned it via ellipse fading.

The experimental design does not answer the question of whether background fading, ellipse fading, or both, led to the superior performance of the Program Group in learning the circle-ellipse discrimination. However, the comparable performances of both groups in learning the form no-form discrimination suggests that ellipse fading was the critical factor.

Ellipse fading after children mastered form vs. no-form but failed to learn circle vs. ellipse. The three children, 1.5, 13, and 15, who failed the circle-ellipse test (Line F) even after learning the form no-form discrimination, were then given the ellipse-fading series. Only one, Child 15, succeeded in learning the discrimination via ellipse fading, and he made 43 errors (Line G).

Total program after children failed all tests. The two children, 10 and 16, who had failed to learn even form *vs.* no-form by means of the tests were then started at the beginning of the program, with background fading (Line H of Table 2). Child 10 failed to get through the background-fading series; Child 16 made six errors in learning form *vs.* no-form but failed to get through the ellipse-fading series (Line I).

Total errors of successful children in both groups. In the Test Group, Subject 4 learned the circle-ellipse discrimination in his first circle-ellipse test; Subjects 5, 7, and 12 learned the discrimination via the test procedure after they had mastered the form no-form discrimination; Subject 15 required ellipse fading even after he had mastered the form no-form discrimination. Line J of Table 2 summarizes all the errors these children made. A comparison of Lines J and C shows that combined background and ellipse fading produced many fewer errors than any of the combinations of tests and programs in those children who learned the circle-ellipse discrimination.

Figure 4 shows the trial-by-trial progress of the children in the Program Group who learned the circle-ellipse discrimination. Large numbers at the end of the curves identify each child by his ranking. The upward steps on the curves indicate advances of the slide tray after the child made a correct first choice. A small, oblique "pip" indicates that the child selected an incorrect key. Each time the child made an error (except on slide 1) his subse-

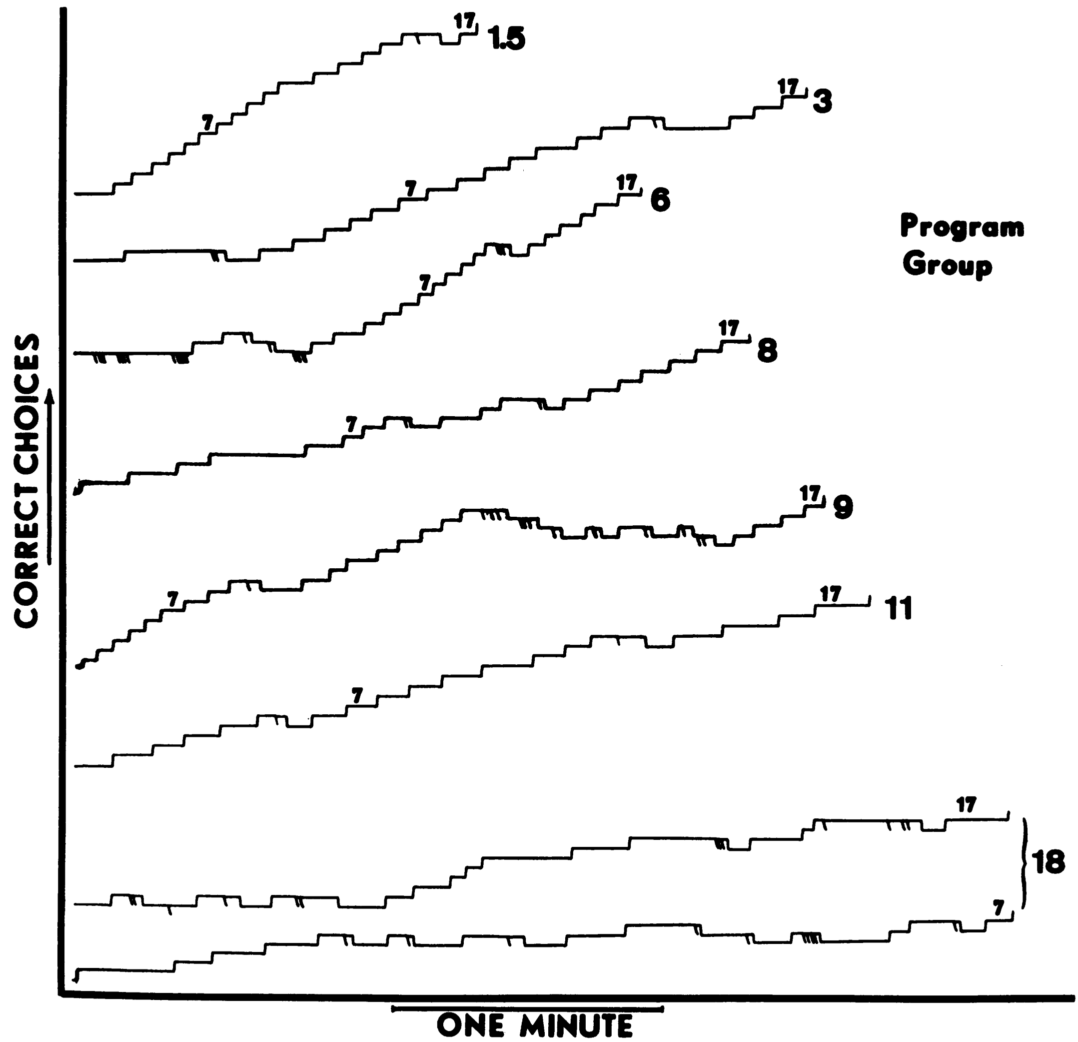

Fig. 4. Trial-by-trial performance of the seven children of the Program Group who learned the circle-ellipse discrimination. Large numbers at the end of each curve identify the children. The numbers 7 and 17 identify the final slides of the background-fading and ellipse-fading series, respectively. The oblique "pips" indicate incorrect choices. Upward steps indicate advances of the slide tray after initial correct choices; downward steps indicate reversals of the slide tray on correct choices that follow errors.

quent correct choice caused the slide tray to reverse and present the preceding slide again. This is indicated by a downward step. The final slides, 7 and 17, of the background- and ellipse-fading series, respectively, are numbered on each curve.

The child ranked 1.5 in the Program Group learned the circle-ellipse discrimination in less than 2 min. All the others, except Child 18, learned the discrimination in 3 min or less; Subject 18 took 7 min and made the most errors.

Three of the children, 1.5, 8, and 9, learned the form no-form discrimination without error, but performance on the first seven slides did not easily predict how well the child would do on the second part of the program. Child 1.5 made only one error, the first time he was exposed to slide 17; the correction and backup seemed to help him and he chose correctly the next time slide 17 appeared. Child 8 made single errors on slides 9 and 11, but suffered no serious difficulties at these points. On the other hand, Child 9, who easily surmounted an obstacle on slide 10, experienced great difficulty when he reached slide 17 the first time. He made three wrong choices on slide 17, three more after he backed up to slide 16, made an error the next four times he saw slide 15, backed up to slide 13, and then successfully went through to the end of the program. Unlike the other children, Subject 6 had great trouble getting started but finally broke through and made errors on only one more trial. Subject 18 started off well, had great difficulty with slides 6 and 7 of the form no-form series, oscillated for a while between the first two slides of the ellipse-fading series, and then made errors on only two more slides, including his first exposure to slide 17.

The children of the Test Group who finally learned the discrimination show a quite different picture from those of the Program Group. The curves labeled *a* in Fig. 5 show only Subject 4 going through the first circle-ellipse test successfully, although he made many errors in the first few trials. None of the other children learned the discrimination in the first circle-ellipse test, and none succeeded in making even two consecutive correct first choices before meeting the error criterion. These children had no great difficulty when they were then given the form no-form test (curves labeled *b*), but all of them again made many errors when given the circle-ellipse test a second time (curves labeled *c*). Children 5, 7, and 12 learned the discrimination with their second circle-ellipse test. Subject 15, who again met the error criterion on his second exposure to the circle-ellipse test, then experienced much more difficulty with ellipse fading (curve *d*) than any of the children in the Program Group.

Error patterns. A detailed examination of errors indicates that the instructional procedure largely determined those responses called "errors". Furthermore, once the procedure has generated errors, response patterns incompatible with correct responses may be reinforced and hinder the child in learning what the experimenter intends that he learn. Figures 6, 7, and 8 reveal this most clearly, but all children showed the same phenomena to a greater or lesser extent.

Figure 6 shows the trial-by-trial selection of keys by Subject 15, one of the four children of the Test Group who did not learn the circle-ellipse discrimination. The key matrix is represented schematically in the lower central portion of Fig. 6, and the keys are numbered from 1 to 9. The keys this child selected are listed consecutively from left to right for each trial in each series of slides. Wrong choices are indicated by uncircled numbers; correct

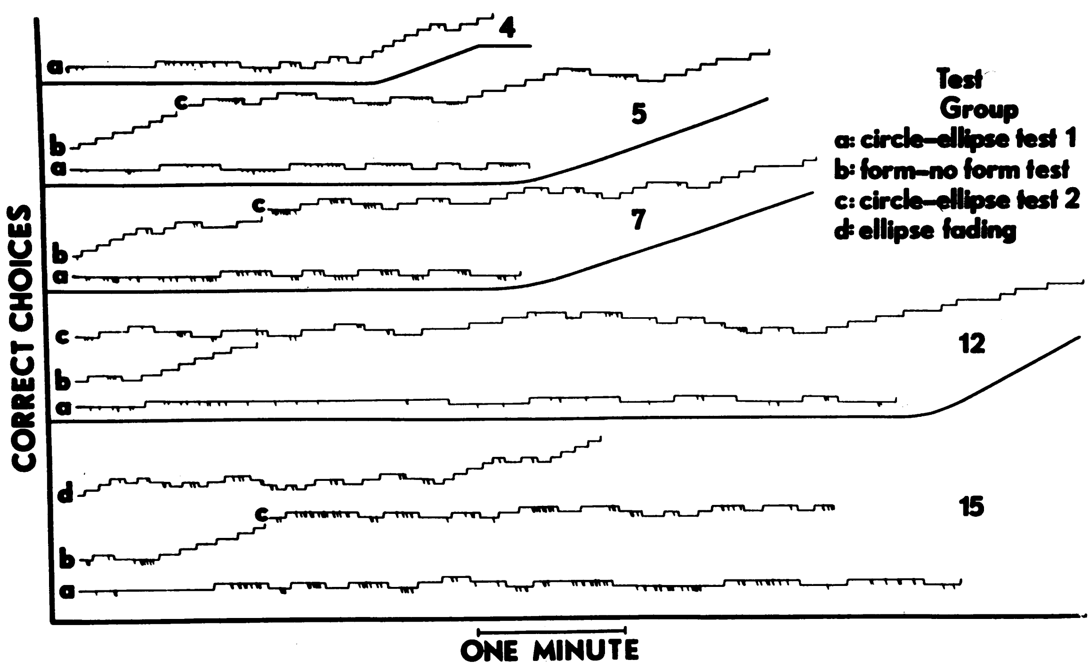

Fig. 5. Trial-by-trial performance of the five children of the Test Group who learned the circle-ellipse discrimination. The lower-case letters mark the beginning of each indicated series of slides. Numbers identify the children. The oblique "pips" indicate incorrect choices.

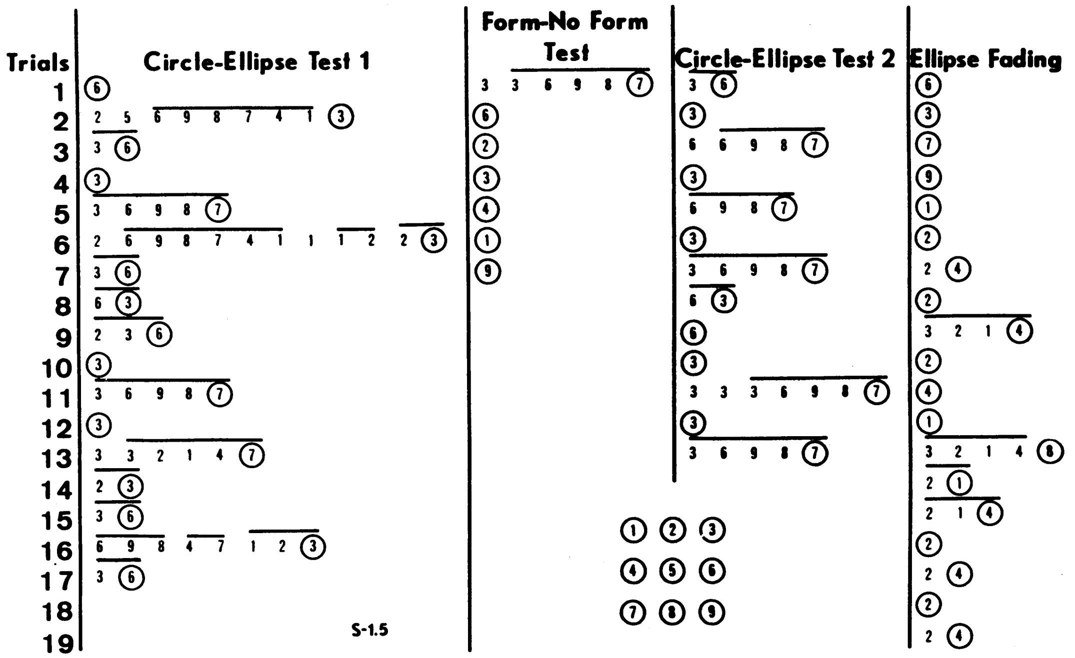

Fig. 6. Trial-by-trial selection of keys by Child 1.5 of the Test Group. The keys are numbered in the schematic illustration of the matrix, and the child's choices are listed from left to right for each trial in four series of slides. The final correct choices are encircled, and a horizontal line is drawn above choices that are adjacent on the outside of the matrix.

choices, which ended each trial, are circled. A line is drawn above all numbers that represent choices of adjacent keys around the outside of the matrix. The frequency with which these lines appear in Fig. 6 indicates that most of this child's errors fell into a specific pattern. He went systematically around the matrix until he arrived at the correct key. This behavior began as early as trial 2 of the first circle-ellipse test, was abandoned after the first slide of the form no-form test, and reappeared on the child's second exposure to the circle-ellipse test.

Circling around the key matrix is undoubtedly a pattern produced by its shape. The child cannot correct an initial error by going immediately to the correct key, as he can in the more usual two-choice discrimination, and circling represents the most efficient search pattern for the child who has not learned the intended discrimination. The child who circles rapidly can still obtain his reinforcers with only a small reduction in reinforcement rate.

However, the shape of the key matrix is a secondary source of the circling behavior. This is shown by Subject 1.5's performance on the form no-form test. After several errors on the first trial, he abandoned his characteristic circling pattern and, instead, selected the correct key first on each trial. Even though picking the correct key increased the child's reinforcement rate only slightly, he adopted this method of responding as soon as he had only to distinguish form and no-form. The second circle-ellipse test presented him again with the more difficult discrimination, and he returned to circling around the key matrix.

When the child was introduced to the ellipse-fading series, he again abandoned his circling pattern during the first six slides, when he could still discriminate the positive and negative keys by means of the contrast between form and background. Although the circling behavior reappeared when it became more necessary to base his discrimination on the forms, a new type of error began to take precedence over circling. He began to "zero in" on key 2 for his first choice on each trial. Although he had pressed key 2 before, not until ellipse fading was key 2 a correct choice on a trial that just preceded errors. An apparatus failure ended the session before he actually reached the error criterion.

In addition to the circling pattern within each trial, Subject 1.5's first response on each trial was also highly determined. On 10 of the 17 trials in the first circle-ellipse test, he pressed key 3 first. With nine keys from which to make his choice, this cannot be considered a chance performance: note that key 3 was actually the reinforced choice on eight of the 17 trials, as a direct result of the backup procedure. Also, seven of the 10 trials on which the child picked key 3 first had been preceded by trials on which key 3 was the correct choice.

In the form no-form test, the child again selected key 3 first, but then abandoned his error pattern in favor of correct responses. On returning to the circle-ellipse test, he immediately resumed his old pattern; he picked key 3 first on nine of the 13 trials.

In the ellipse-fading series, the child's first error (trial 7) was a selection of key 2, the previously correct choice. He then selected key 2 again, correctly this time, moved to his old favorite, key 3, for his second error, returned correctly to key 2, moved without error through keys 4 and 1, made his next error on key 3, and settled on key 2 for the remainder of the series.

Most of Subject 1.5's errors were clearly related to sources of reinforcement irrelevant and even inimical to the specified contingencies. The errors may be classified as: adventitiously reinforced sequences (circling), selecting the most frequently reinforced key, selecting the key that was correct on the preceding trial, and initial position preference.

All the children showed errors like those of Subject 1.5, and some of the records illustrate the error patterns even more clearly. They help to explain why four children, 1.5, 10, 13, and 16, failed to learn the circle-ellipse discrimination even after they were given the opportunity to learn the preliminary form no-form discrimination or to go through a portion of the fading program. Figure 7 shows the pattern of first choices by another child (Subject 10) who failed to learn the circle-ellipse discrimination.

In Fig. 7, the solid dots connected by solid lines show the key selected first on each trial; the open dots connected by broken lines represent the correct key. Because of the correction procedure the correct key was always the last key selected on each trial. The key numbers do not represent a continuous dimension, but the points are connected to clarify the trends visually; these would remain the same regardless of the order in which the keys were arranged on the ordinate. Open and closed circles at the same position mean that the child's first choice on a trial was correct; when the solid line is horizontal, it shows that the same key was selected first on successive trials; a black dot located at the same key position as the open circle on the preceding trial indicates that the first choice was a repetition of the key that had been correct on the previous trial.

In the circle-ellipse test, Child 10 never picked a correct key on his first choice. There was no obvious factor governing his choices during this test. He was then given the form no-form test; his first choice, key 7, was correct, and from that point on, he was "caught". In 10 trials of the form no-form test, followed by 16 trials on the background-fading series of the program, Child 10's first choice was key 7 on all but two trials. Because of the backup procedure, a child who restricted his first choice to a single key would be correct on 50% of the trials. For a retarded, institutionalized child, a 50:50 immediate payoff may represent great riches indeed.

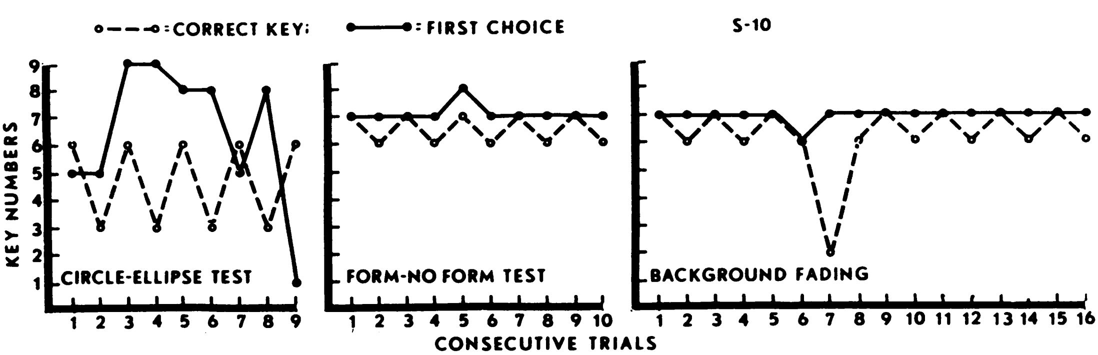

Fig. 7. Test Group Subject 10's first choice and the correct key on each trial. Because of the correction procedure, the correct key was always the last choice on each trial.

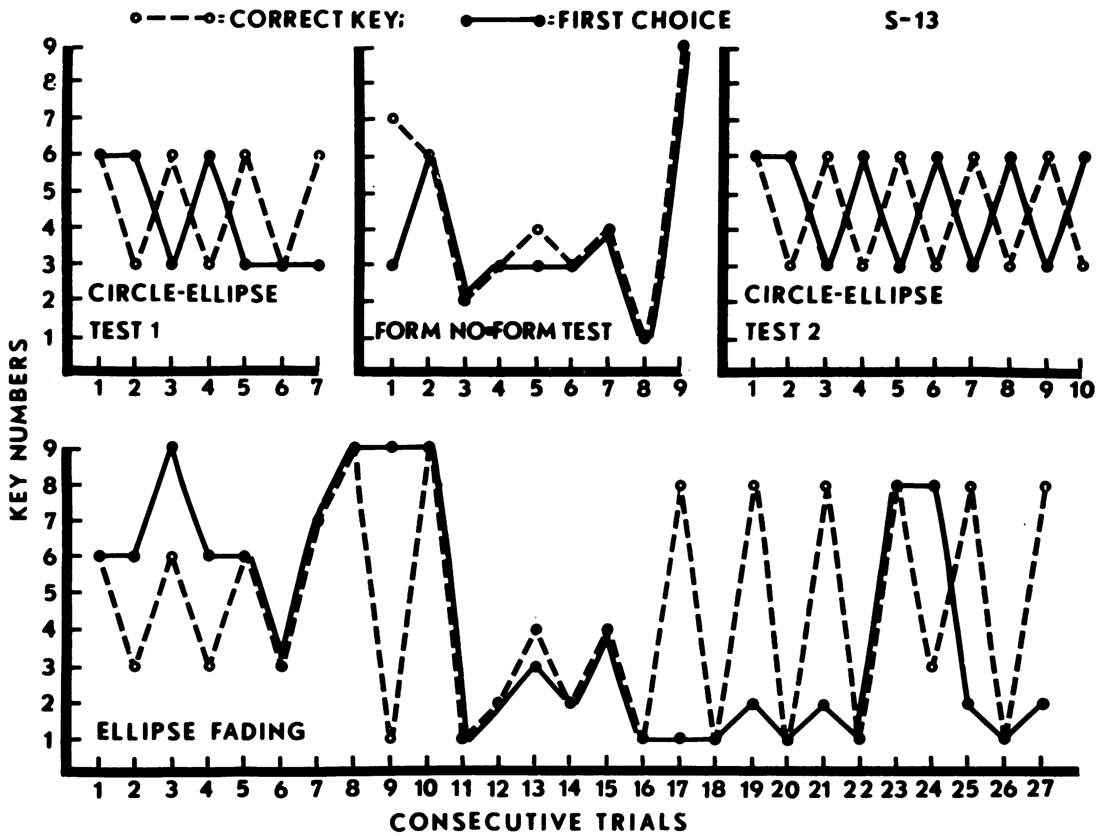

Fig. 8. Test Group Subject 13's first choice and the correct key (last choice) on each trial.

Child 13 (Fig. 8) quickly developed a pattern of selecting the key that had been correct on the preceding trial, as may be seen in the first five trials of circle-ellipse test 1. On trial 5 of the first test he "zeroed in" on the previously correct key 3; continued this way on the first trial of the form no-form test; and then, with one exception, shifted to correct choices. When the child was again given the circle-ellipse test series, the initial pattern reappeared immediately. On trials 2 to 10, his first choice was always the key that had been correct on the preceding trial.

On four of the first five trials of the ellipse-fading series, the child shifted his first choices to key 6, which, along with key 3, had been the most frequently reinforced response in the preceding set of slides. He then abandoned this pattern of behavior and made only a few errors while the required performance was still little different from the form no-form discrimination. As the ellipses became more distinct, the child again began to make errors. On trials 16 to 22, he selected key 1 five times. His first selection on trials 19 and 21 was key 2 and he followed this initial choice each time (not shown in the figure) by picking keys 7 and 8 in succession. Key 8 was correct on trials 17, 19, and 21. The child appeared to be developing an adventitiously reinforced sequence of key presses: key 1 correct, and then keys 2, 7, and 8. Key 8 finally broke through as a correct first choice on trial 23, and was repeated as an error on trial 24. On trials 25 and 27 the child returned to key 2 as his first choice, but he shortened his error sequence by moving immediately to key 8.

It may be noted that Subject 13 did not meet the error criterion in circle-ellipse test 1 or in ellipse fading because he refused to continue with those series.

DISCUSSION

The data clearly support the inference that stimulus-shaping techniques can teach retarded children more effectively than a technology which generates errors and depends only on the processes of reinforcement and extinction. This is consistent with related findings reported for normal children (Hively, 1962; Holland and Matthews, 1963; Moore and Goldiamond, 1964; Suppes and Ginsberg, 1962) and for retarded children (House and Zeaman, 1960; O'Connor and Hermelin, 1963).

The teaching program greatly reduced the children's errors in learning the circle-ellipse discrimination, but it did not completely eliminate errors. The types of errors by both groups of children were like those other investigators have described (*e.g.*, Harlow, 1950; Levine, 1965). The trial-by-trial analysis, however, indicated that errors were nearly always traceable to reinforcement contingencies inherent in the teaching techniques and conflicting with contingencies deliberately designed to help the children to learn. Miles (1965) has expressed a similar conclusion. The children who failed to learn the final performance did learn many other things, all reasonable and none requiring that their learning processes be categorized as other than normal.

These findings strongly suggest that error analyses, rather than supporting a principle like, "Learning is a process of error elimination" (*e.g.*, Harlow, 1959), serve only to reveal where uncontrolled factors have crept in to interfere with the variables the experimenter or teacher has specified as being relevant to his methodology.

The data of those Test Group children who did not learn the circle-ellipse discrimination showed that once a given error pattern was reinforced, that pattern often was adopted again when the children reached a difficult portion of the program. It is unclear, therefore, whether children who eventually learned the circle-ellipse discrimination after failing the first test did so because of the training in the preliminary steps or because of the additional reinforcement and extinction.

Perhaps more surprising than the fact that some children in the Test Group failed to learn the discrimination is the fact that some of them did learn. Errors like perseveration on a single key, circling around the key matrix, or more complex response sequences permitted the children to maintain relatively high rates of reinforcement. In spite of this, they tended to show a remarkably great sensitivity to the consequences of their first choice on each trial. Most of the children, when they were returned to an easier task, abandoned their error pattern in favor of correct choices. Only when they were again exposed to the same situation that had originally generated an error pattern did they return to a less adequate form of behavior.

Procedural features like correction and backup, along with the shape of the key matrix, dictated specific types of error patterns. But procedural "artifacts" did not initiate error patterns, although they did determine their form. For example, children in the Test Group abandoned their error patterns when they were required to make less complex discriminations. Also, children in the Program Group who learned the circle-ellipse discrimination made the same types of initial errors as those in the Test Group, but their initial errors did not lead them to adopt error patterns as alternatives to correct choices. The appearance of error patterns, then, must be attributed primarily to the relative ineffectiveness of extinction as a teaching technique. This conclusion supports the practical sanction against allowing children to make errors in a teaching situation.

These observations also reveal a methodological problem of some importance. The general experimental design, pre-test—instruction—post-test, may yield misleading data about the efficacy of an instructional technique because of the error patterns the subjects develop during the pre-test. One answer to this problem is the procedure suggested by Holland (1961), in which the instructional process is stopped and revised before the child develops a definite error pattern. The effectiveness of the instruction technique is then evaluated not in terms of pre-test and post-test performances, but in terms of the child's progression through the teaching program and his attainment of the specified behavior.

The success, with retarded children, of a teaching method that reduced errors, along with the identification of errors as the product of normal processes, should not be interpreted as meaning that retarded children are simply products of inadequate instruction. A more valid inference is that their capabilities have been underestimated. More effective instructional methods than those in general use now are available to estimate behavioral potential in children limited by developmental or acquired abnormalities.

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